



Part C Early Intervention dosage and growth in adaptive skills from early childhood through adolescence

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ABSTRACT

The present study explored the association between the dosage level of Part C Early Intervention (EI) services and growth in adaptive behavior from early childhood through adolescence for children with developmental disabilities. Children who received more hours of service than expected based on their characteristics and those of their family measured at EI intake had greater skills in communication, socialization, and daily living skills when they ended EI services at EI. In addition, children who received more hours of service showed greater improvements in all three domains of adaptive behavior over time. The short- and long-term benefits of higher dosage levels of EI services suggest that Part C EI practices and policies should be geared toward increasing service hours, either by increasing the number of hours of scheduled service or minimizing disruptions to scheduled service.

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1. Introduction

One of the major tasks for all children, including those with developmental disabilities, is to acquire skills in adaptive behavior. Adaptive behavior includes skills that individuals typically use to meet the personal and social demands of daily life (Lambert, Nihira, & Leland, 1993), including abilities needed for communication, socialization, and daily living activities (Sparrow, Balla, & Cicchetti, 1985). In contrast to assessments of intellectual functioning, assessments of adaptive behavior focus on the tasks that children engage in routinely rather than the ones that they have the capacity to demonstrate but may use only rarely (Widaman & McGrew, 1996).

There is a small body of research on the growth of adaptive behavior for children with developmental disabilities. These studies indicate that children with intellectual disability (Chadwick, Cuddy, Kusel, & Taylor, 2005) and children with a range of developmental disabilities (Shonkoff, Hauser-Cram, Krauss, & Upshur, 1992) are at risk for lower levels of adaptive functioning than typically developing children. Moreover, analyses of trajectories of

adaptive behavior indicate that, although children with developmental disabilities demonstrate growth in these skills, they seldom reach levels of functioning displayed by typically developing children during the early and middle childhood years (Chadwick et al., 2005; Dieterich, Hebert, Landry, Swank, & Smith, 2004; Hauser-Cram, Warfield, Shonkoff, & Krauss, 2001).

Few studies, however, have assessed whether aspects of early childhood intervention relate to changes in children's adaptive functioning within this population. Baghdadli and colleagues (Baghdadli et al., 2012) modeled trajectories of adaptive development over 10 years for children with autism spectrum disorder (ASD) in France. Adaptive behavior was assessed at three time points (at approximately ages 5, 8, and 15), and the number of hours of specialized interventions received per week over the course of the first three years of study participation were gathered by research staff during interviews. Greater hours of intervention increased the likelihood of following a trajectory of greater growth in communication skills.

Anderson, Oti, Lord, and Welch (2009) investigated trajectories of social skills over the course of 11 years from toddlerhood through adolescence for three groups of children: (1) children with autism spectrum disorder, (2) children with pervasive developmental disorder-not otherwise specified (PDD-NOS), and (3) children with developmental delays. Data on the number of hours

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of both educational and specific (e.g., Applied Behavior Analysis) treatments from toddlerhood through age 5 were gathered from parent diaries and interviews. Intervention intensity for each child was characterized as “none,” “some,” or “more” with the categories of “some” and “more” representing, respectively, groups below and above the median of the distribution of total hours, not including zero. All three diagnostic groups experienced significant growth over time, but the rate of growth was slowest for children with ASD. Controlling for diagnostic group membership, children receiving “more” hours of intervention made significantly greater gains over time than children in both the “some” and “none” categories.

Although evidence on the relation between early childhood services and change in children’s adaptive behavior is sparse, it is suggestive of a dosage effect. Overall, past studies provide evidence of improvement in social and communication skills for individuals with ASD as a result of greater hours of specialized intervention. These findings are consistent with existing research suggesting that these domains are amenable to change during early childhood (McConnell, 2002; Rogers, 2000). However, studies have primarily reported findings for children with ASD receiving fairly specific and intensive therapeutic interventions, in contrast to Part C Early Intervention services. In addition, the majority of studies have not isolated the influence of intervention from that of other child characteristics.

1.1. Early Intervention services

The Education for All Handicapped Children Act Amendments of 1986 (PL 99–457) established the Part H program (subsequently renamed Part C) with the purpose of enhancing the development of infants and toddlers with developmental disabilities from birth to 3 years. In the United States, Part C Early Intervention (EI) services are central during early childhood for children with developmental delays and disabilities. Similar programs exist in other countries as well (Guralnick, 2011). EI programs target infants and toddlers, as research suggests that optimal child development is formed by the quality and timing of experiences during the first years of life (Shonkoff & Phillips, 2000). Additionally, the program was designed to provide a system of supports to increase the capacity of families to meet these children’s needs (Guralnick, 2011).

Several researchers have found that EI services for children with disabilities are associated with significant improvements in children’s developmental trajectories as well as enhanced experiences within families (Guralnick, 2011; Hebbeler et al., 2007; Warfield, 1994). Nevertheless, to date, there is little information examining the long-term development of children in relation to the EI services they received. There is evidence, however, that early childhood programs can have sustained effects on children’s competence and adaptive functioning into adolescence and adulthood from analyses of programs such as the Abecedarian Project, Perry Preschool and the Chicago Parent Child Program (Barnett & Masse, 2007; Belfield, Nores, Barnett, & Schweinhart, 2006; Reynolds, Temple, Robertson, & Mann, 2002).

A follow-up investigation of the largest longitudinal study in the United States of early intervention services ($N=298$), the National Early Intervention Longitudinal Study (NEILS), reported that a low percentage of the children served met developmental milestones in motor, cognition, communication, and independence skills by kindergarten (Scarborough, Hebbeler, Spiker, & Simeonsson, 2011). Only 18% of those with a diagnosed disability, 31% of those with developmental delay, 40% of those who had an “at risk” condition, and 50% of those with an exclusive speech or language delay reached developmental milestones expected by 60 months of age. The relations between features of EI services and children’s developmental milestones were not explored, however.

1.2. Established approaches to quantifying level of EI services

Researchers have primarily relied on three approaches to quantifying level of EI services in consideration of developmental outcomes: duration, intensity, and comprehensiveness (Guralnick, 1998; Ramey & Ramey, 1998). *Duration* involves the length of time in service. In EI, duration is often related to age of intake, as children who enter these services at an earlier age are likely to have a longer duration of service (Hebbeler et al., 2007). Children and families can leave EI before age 3, but only a low percentage do (Hebbeler et al., 2007). The process of making a referral to EI also affects duration. Since the majority of referrals to EI are made by pediatricians and other health care personnel, the age at which a condition can be diagnosed and/or when delayed development can be detected varies (Bailey, Hebbeler, Scarborough, Spiker, & Mallik, 2004; Hauser-Cram & Warfield, 2009; Scarborough et al., 2004). Thus, some children (e.g., children with genetic disorders such as Down syndrome) enter EI soon after birth, whereas other children (e.g., those with a language delay) may not enter until age 2 or later.

Intensity has generally been defined as hours of contact by an interventionist with a child and/or parents within a specified time frame, such as one week (Innocenti & White, 1993). Excluding the intensive services provided in some states for children diagnosed with ASD (Henderson, 2011), early intervention services average to about 2–3 h a week (Hallam, Rous, Grove, & LoBianco, 2009; Hebbeler et al., 2007).

Comprehensiveness involves the number of different services a child and family receive to meet their needs. Types of services have been categorized in two ways. One approach has been to examine the list of child and family services defined in the Part C regulations as appropriate for EI, including occupational and speech therapy, parent information and training, service coordination, parent support groups, and the array of different providers (e.g., educators, therapists, nurses, social workers) with expertise to provide these services (Epley, Summers, & Turnbull, 2011). A second approach has been to categorize services based on where they are provided (e.g., home or center), whether they are group-based or one-on-one, and whether they include the child only, the parent only (e.g. parent support groups) or the parent and child together (Shonkoff et al., 1992). For the purposes of this study, the former will be referred to as *comprehensiveness of provider* and the latter will be referred to as *comprehensiveness of format*.

1.3. Challenges to assessing the impact of EI services

Evaluating the impact of Part C EI services is challenging due to the myriad of services available, individualized service provision, and policies which mandate that services be available to all children who meet eligibility requirements (Guralnick, 2005). Children with greater need based on their developmental profile at intake will receive more weekly Part C EI services (intensity) over a greater length of time (duration) from a wider range of providers (comprehensiveness of provider) in a broader range of formats (comprehensiveness of format). The amount and type of services received are guided by Individualized Family Service Plans (IFSPs) that are jointly developed by families and service providers and re-evaluated and re-defined over time depending on the child’s progress and the changing needs and desires of the family (Hauser-Cram & Warfield, 2009). Using only the established approaches to quantifying level of EI service may be misleading because children with greater duration, intensity and comprehensiveness are likely to show fewer gains in adaptive skills over time, purely as a function of their initial developmental challenges.

The second challenge to assessing impact of EI services on child outcomes is the mandate that services be available to all children who meet eligibility requirements. Conventional experi-

mental approaches are, therefore, unobtainable and unethical. Prior to the implementation of Part C services, however, several studies did utilize random assignment and other quasi-experimental group-based designs to assess effectiveness. Meta-analyses of different combinations of these studies reached somewhat different conclusions as to whether or not service intensity influenced outcomes. [Innocenti and White \(1993\)](#) refer to earlier meta-analyses and reviews that suggested the benefits of greater intensity and longer duration of early intervention services, although they did not find sufficient evidence of a dosage effect on outcomes for children in EI across the studies reviewed. [Shonkoff and Hauser-Cram \(1987\)](#) found that early intervention was more effective when efforts were family-focused (i.e., targeting both the child and parents) and structured. There was general agreement across studies that better measures of early intervention services, specifically of intensity, and family characteristics are needed ([Casto & Mastropieri, 1986](#); [Innocenti & White, 1993](#); [Shonkoff & Hauser-Cram, 1987](#); [White & Casto, 1985](#)).

1.4. Novel approach to assessing dosage effects

In response to these methodological challenges, the present study utilizes a novel approach to estimating dosage effects of Part C services on growth in adaptive behavior. The concept of dosage is well established in the literature on the impacts of child care ([Zaslow et al., 2010](#)). In this literature, dosage has been operationalized as either current participation (i.e., hours of participation per day or week) or cumulative participation (i.e., total hours or days over a period of years). Given the generally low intensity of EI services per week and the range and variation of individualized services over time ([Hebbeler et al., 2007](#); [Shonkoff et al., 1992](#)), cumulative participation is a more useful construct to measure Part C EI services.

Cumulative participation in child care is not determined by child characteristics, unlike EI services. To address this challenge, the present study defines dosage as the number of hours of service (per month) above or below the number of hours of service expected, based on child and family characteristics measured at EI intake. The present study examines change in domains of adaptive behavior (communication, socialization, daily living skills) from early childhood (age 3) through adolescence (age 18) as a function of EI service use based on service records collected from program entry to exit (i.e., intake to age 3). Analyses include established measures of EI services (duration, intensity, comprehensiveness of provider, comprehensiveness of format) as well as an estimate of dosage.

2. Methods

2.1. Participants

Data for the present study were drawn from the Early Intervention Collaborative Study, a longitudinal investigation of children with developmental disabilities and their families ([Hauser-Cram et al., 2001](#); [Shonkoff et al., 1992](#)). Participants were recruited at the time of their children's enrollment in 29 publicly funded early intervention (EI) programs in Massachusetts and New Hampshire over a two-year period (1985–1987). Families were invited to participate if their child was less than 24 months old with a diagnosis of Down syndrome, motor impairment, or developmental delay of unknown etiology. These diagnostic categories were selected to represent the most common types of disability served by EI at that time ([Shonkoff et al., 1992](#)). Medical records for each enrolled child were reviewed by research staff to confirm type of disability. Additional characteristics of the children and their families are reported in [Shonkoff et al. \(1992\)](#) and [Hauser-Cram et al. \(2001\)](#). Families who were eli-

Table 1
Descriptive statistics.

	Sample size	M (SD)
Child characteristics at study entry		
Number of months premature	162	0.38 (0.79)
Cognitive skills	162	64.71 (24.04)
Adaptive behavior ^a	162	7.28 (5.25)
EI services		
Age at intake (in months)	162	8.91 (6.62)
Intensity ^a	162	7.25 (3.92)
Duration ^b	162	24.56 (7.65)
Comprehensiveness of providers ^c	162	5.63 (1.91)
Comprehensiveness of formats ^d	162	3.72 (1.09)
Communication skills ^e		
Age 3	162	1.94 (0.94)
Age 5	154	2.86 (1.35)
Age 10	142	5.70 (3.21)
Age 15	127	7.50 (4.78)
Age 18	124	8.85 (5.71)
Socialization skills ^e		
Age 3	162	1.61 (0.63)
Age 5	154	2.63 (1.14)
Age 10	142	4.82 (2.66)
Age 15	127	6.99 (4.35)
Age 18	124	9.64 (5.99)
Daily living skills ^e		
Age 3	162	1.65 (0.56)
Age 5	154	2.69 (1.11)
Age 10	142	5.27 (2.69)
Age 15	127	7.42 (4.52)
Age 18	124	9.60 (5.78)

^a Number of early intervention hours received per month on average.

^b Number of months of EI service.

^c Number of different EI formats (e.g., home visit).

^d Number of different EI providers (e.g., speech therapist).

^e Age equivalent scores.

gible for the study but who declined to participate ($n=49$) were more likely to have a mother working full time outside the home, $\chi^2(2, N=233)=10.12, p<0.01$, and to have a child categorized with developmental delay of unknown etiology, $\chi^2(2, N=239)=19.96, p<0.001$. No significant differences were found in family income, marital status, or maternal education between families who participated and those who did not ([Shonkoff et al., 1992](#)).

The analyses for this study focused on 162 children with complete monthly EI service records. Included in the sample were 50 children with Down syndrome, 63 with motor impairment, and 49 with developmental delay of unknown etiology. Age at EI intake ranged from 0.31 to 25.13 months ($M=8.91, SD=6.62$). Seventeen percent of the children also had a seizure disorder. Slightly more than half of the children were male (54%). The majority of children were of European-American descent (91%), which was representative of the states from which they were recruited at the time. Over one-third (37%) were firstborn children. At study entry, 83% of parents were married. The median household income at the start of the study was \$25,000–30,000, reflecting the median household income in the Northeast of the U.S. at the time when data were collected. The average number of years of maternal education was 13.90 ($SD=2.35$). Mothers ranged in age from 18 to 43 ($M=29.58, SD=4.78$). Less than half of mothers were employed at least part-time (38%). Additional descriptive statistics measured at the start of the study are presented in [Table 1](#).

2.2. Procedure

This study used data collected across 7 time points. Families were visited in their home within 6 weeks of entry into an EI program (Time 1) and subsequently 12 months later (Time 2). Families

were visited again when their child was age 3 (Time 3), age 5 (Time 4), age 10 (Time 5), age 15 (Time 6), and age 18 (Time 7). At each time point, families were visited by two staff members trained to be reliable on all measures used in data collection. While one staff member conducted a multidimensional, structured assessment of the target child, the other staff member interviewed the mother. The mother interview included an evaluation of the child's adaptive behavior, questions about demographic information, questionnaire data, and specific questions about raising a child who had early onset developmental disabilities. The home visits lasted approximately 1–3 h. A packet of additional data collection forms were left for the mother and father to complete at a later time and send back to the project office. Participants were compensated for their time.

2.3. Measures

Research assistants were trained on the Bayley Scales of Infant Development and the Vineland Adaptive Behavior Scales until the level of reliability required by each measure was obtained. Reliability was checked throughout the study.

2.3.1. Family characteristics

Family income, maternal years of education, and maternal marital status were recorded at Time 1.

2.3.2. Child characteristics

Child type of disability was coded as 1 = *Down syndrome* and 0 = *motor impairment or developmental delay* of unknown etiology to distinguish between diagnoses with known and unknown genetic causes. Child gender was coded as 1 = *male* and 0 = *female*. At Time 1, mothers reported the number of months their child was premature (with full-term births coded as 0). Mothers also reported whether or not their child had a seizure disorder (1 = *yes*, 0 = *no*) at the start of the study.

2.3.3. Early Intervention services

The child's age at intake for early intervention was recorded at Time 1. Monthly services records were completed by early intervention staff to compile comprehensive data on the quantity, type, and discipline of the provider for all program services delivered to participating children and their families. Service hours and type of services were determined based on the Individual Family Service Plan (IFSP). Hours of service provided (in contrast to hours planned) were recorded within one quarter of an hour. Each monthly form was checked by the research staff and any questions or problems were reviewed with the service program. Periodic visits to programs were made by research coordinators to cross-check original service files and corresponding monthly service records for a randomly selected subsample of participating children.

Service intensity was defined as the average number of hours of service received per month. It was calculated by dividing the total number of service hours received (from EI entry to exit) by the total number of months each child and family had participated in the EI program. Service duration was defined as the number of months each child and family had received EI services. The comprehensiveness of format was defined as the number of different locations of service receipt and the recipient(s), including home visits, center-based individual child treatments, center-based individual parent treatments, center-based individual parent-child treatments, center-based child groups, and center-based parent-child groups. The comprehensiveness of provider was defined as the number of different types of professionals who provided EI services to the child, including educator, physical therapist, occupational therapist, speech and language pathologist, social worker, nurse/nurse practitioner, psychologist, physician, paraprofessional,

and other. The method of determining dosage is described in the analytic plan.

2.3.4. Child cognitive skills

The Mental Scale of the Bayley Scales of Infant Development (Bayley, 1969) was used as a measure of child cognitive skills at Time 1. The Mental Scale consists of 163 items assessing object relations, perceptual-motor skills, memory, learning, problem-solving ability, and early communication through a series of tasks presented to the child by the staff member. The standard score was used in this study, which adjusts for gestational age for children born prematurely. The Cronbach's alpha for the present sample was $\alpha = 0.99$.

2.3.5. Child adaptive behavior

Child adaptive behavior was assessed using the Vineland Adaptive Behavior Scales-Interview (VABS; Sparrow, Balla, & Cicchetti, 1984) at each time point. At Time 7, the second edition of the VABS was used (VABS-II; Sparrow, Cicchetti, & Balla, 2005). In order to compare scores across time points, raw scores were converted into age equivalent scores (in years) for the communication, daily living skills, and socialization domains following procedures in the manual. The VABS was completed through a semi-structured interview with the mother during home visits at each time point to identify skills the child does not demonstrate (0), demonstrates with help (1), or independently demonstrates (2) on a regular basis. VABS scores at Times 3 through 7 (age 3–18) were used as outcome variables in the main analyses focused on change in adaptive behavior over time. VABS scores at Time 1 were used to estimate the number of hours of expected service (in addition to several other child and family characteristics) at EI entry, in order to create the dosage variable. The VABS has demonstrated good reliability (Sparrow et al., 1984) and validity (Middleton, Keene, & Brown, 1990). Cronbach's alphas in the present sample ranged from $\alpha = 0.90$ – 0.99 for communication skills, $\alpha = 0.88$ – 0.99 for daily living skills and $\alpha = 0.90$ – 0.98 for socialization skills across time points. Descriptive statistics for predictor and outcome variables are presented in Table 1.

2.4. Analytic plan

Previous analyses with this sample identified patterns of EI service receipt based on several child and family characteristics (Shonkoff et al., 1992). These characteristics included family income, age at EI intake, prematurity status, presence of a seizure disorder, cognitive skills, and adaptive skills. These characteristics were measured at Time 1, within 6 months of EI entry. To estimate the number of hours of service expected for each child, an ordinary least squares regression was first conducted with child and family characteristics at Time 1 predicting the average number of hours actually received per month from Time 1 to Time 3 (EI entry through age 3). Predicted values were saved as new variables from the regression analysis. The predicted value represents the number of hours of service expected for that child.

The regression findings indicated that higher family income was associated with more EI hours per month, $\beta = 0.21$, $p < 0.01$. Older age at EI intake was associated with more EI hours per month, $\beta = 0.17$, $p = 0.05$. Cognitive skills were inversely associated with the number of EI hours per month, such that children with higher cognitive skills received fewer EI hours, $\beta = -0.26$, $p < 0.01$. The remaining variables were not significantly predictive of the number of EI hours received per month. The overall regression model accounted for 18% of variance in the average number of EI hours received per month.

Next, the difference between the predicted number of hours received per month and the observed number of hours received per month was then calculated for each child to capture dosage. For

Table 2
Unconditional models for domains of adaptive behavior.

Fixed effect	Communication skills		Socialization skills		Daily living skills	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Average initial status, γ_{00}	1.86	0.07***	1.76	0.06***	1.64	0.06***
Average instantaneous rate of growth, ^a γ_{10}	0.60	0.04***	0.33	0.04***	0.52	0.03***
Average acceleration, γ_{20}	-0.01	0.002***	0.01	0.003***	-	-
Random effect	Communication skills		Socialization skills		Daily living skills	
	Standard deviation	Variance component	Standard deviation	Variance component	Standard deviation	Variance component
Average initial status, u_0	0.65	0.43	0.54	0.29	0.26	0.07
Average instantaneous rate of growth, ^a u_1	0.33	0.11***	0.29	0.09**	0.33	0.11***
Average acceleration, u_2	0.01	0.0002	0.02	0.001***	-	-
Level-1 effect, r	1.15	1.33	1.23	1.51	1.16	1.35

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

^a Average slope for daily living skills.

example, a child was predicted to receive 10 h of service per month based on his developmental level and other background characteristics measured at EI intake (predicted value). Yet, in reality, this child only received 8 h of service per month (observed value). This child received a value of -2 for dosage, to reflect the fact that he received two fewer hours than expected.

Following the creation of the EI dosage variable, hierarchical linear modeling (HLM) was used to examine associations between dosage and long-term functioning, with multiple measurement occasions (Level-1), nested within individual children (Level-2). These analyses were conducted using HLM software version 6 (Raudenbush, Bryk, Cheong, & Congdon, 2004). Following recommendations from Raudenbush and Bryk (2002), unconditional growth models were first fit to the data to establish the shape of growth over time prior to the inclusion of Level-2 predictors. Child age was centered at 3 years, the end of children's eligibility for early intervention services. Previous analysis of this sample showed a pattern of linear growth in domains of adaptive behavior from EI entry through age 10 (Hauser-Cram et al., 2001). There is evidence that skills in adaptive behavior may plateau after middle childhood for children with developmental disabilities (Dykens, Hodapp, & Evans, 2006); therefore, a quadratic growth term was included as the highest order polynomial in each unconditional model. Since scores were centered at age 3, the intercept represents levels of adaptive behavior at the end of EI eligibility, the linear term represents the average instantaneous rate of growth at age 3, and the quadratic term represents average acceleration.

Subsequent to identifying the shape of growth over time for each of our three outcomes, conditional models were fit that included EI service intensity, duration, comprehensiveness of format, comprehensiveness of provider, and dosage at Level-2. The correlations among these predictors ranged from non-significant to $r = 0.43$, below the conservative $r = 0.70$ threshold that causes concern for multicollinearity. Each of these variables was centered around its grand mean to capture differences between individuals. In addition to EI service variables, family background variables (maternal marital status, family income), type of disability indicator variables (Down syndrome vs. other, motor impairment vs. other), and age at EI intake were included at Level-2. The remaining child and family characteristics measured at Time 1 (number of months premature, presence of a seizure disorder, cognitive skills, and adaptive skills) were not significant predictors and were, therefore, omitted from the final models for parsimony.

2.5. Missing data

Of the 162 families in the analytic sample, 16 families (9.9%) dropped out after age 5, 12 families (7.4%) dropped out after age 10, and 10 families (6.2%) dropped out after age 15. One hundred twenty-four families (76.5%) remained in the study until age 18. Most of these families had complete data on the outcome variable, however, 15 of the 124 families were missing data on the outcome variable at one or more previous time points (e.g., because they skipped a time point). Families who remained in the study through age 18 were compared to families who dropped out before age 18 on a variety of characteristics measured at the start of the study, including family income, maternal marital status, and child age at EI intake, gender, type of disability, prematurity, seizure disorder, and cognitive and adaptive skills. There was a significant difference in maternal marital status only, $F(3, 158) = 3.96$, $p < 0.01$. Post-hoc analyses revealed that mothers who remained in the study through age 18 were significantly more likely to be married (87% were married) than mothers who dropped out of the study after age 15 (50% were married), $p = 0.02$. Maternal marital status was included as a predictor in the main analyses.

Missing data were imputed using the Markov Chain Monte Carlo procedure in SPSS version 19. There were no missing values on variables used to estimate EI dosage or those used as predictors in the main analyses. Approximately 10.39% of values on the outcomes variables across time points were missing, either due to attrition or skipped time points. Taken together, 6.45% of values across all variables were missing. Although there is little consensus on the number of imputed data sets needed, one imputed data set per percentage of data missing (e.g., 5 imputed data sets for 5% missing data) has been recommended in the literature (White, Royston, & Wood, 2011). Given this recommendation, we created 10 imputed data sets to more than adequately address the percentage of missing values. Results were pooled across the imputed data sets, since excluding cases with missing data biases estimates and reduces statistical power (Widaman, 2006). The HLM software automatically pools coefficient estimates across multiple imputed data sets.

3. Results

The results are presented for the three domains of adaptive behavior in turn: communication, socialization, and daily living. Scores on these domains were highly correlated across time points, ranging from $r = 0.73$ to $r = 0.92$.

Table 3
Conditional models for domains of adaptive behavior.

Fixed effect	Communication skills		Socialization skills		Daily living skills	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Average initial status						
Intercept, γ_{00}	1.89	0.20***	1.55	0.17***	1.53	0.19***
Mother married, γ_{01}	0.28	0.16	0.46	0.15**	0.20	0.19
Family income, γ_{02}	0.17	0.03***	0.09	0.03**	0.05	0.03*
Down syndrome vs. other, γ_{03}	-0.79	0.21***	-0.46	0.22*	-0.06	0.22
Motor impairment vs. other, γ_{04}	-0.03	0.15	-0.07	0.15	-0.11	0.15
Age at EI intake, γ_{05}	0.05	0.02**	0.05	0.02**	0.07	0.01***
Intensity, γ_{06}	-0.49	0.04***	-0.40	0.05***	-0.28	0.05***
Duration, γ_{07}	-0.01	0.01	<0.01	0.01	0.01	0.01
Comp. of format, γ_{08}	-0.07	0.06	-0.10	0.06	-0.06	0.05
Comp. of provider, γ_{09}	0.02	0.03	0.01	0.03	0.04	0.03
Dosage, γ_{10}	0.50	0.05***	0.40	0.05***	0.28	0.05***
Average instantaneous rate of growth^a						
Intercept, γ_{10}	0.64	0.13***	0.50	0.14***	0.56	0.08***
Mother married, γ_{11}	0.02	0.12	-0.26	0.13*	0.03	0.08
Family income, γ_{12}	0.06	0.02**	0.08	0.02***	0.06	0.01***
Down syndrome vs. other, γ_{13}	-0.14	0.14	0.10	0.15	-0.23	0.09**
Motor impairment vs. other, γ_{14}	-0.03	0.09	0.03	0.10	-0.01	0.06
Age at EI intake, γ_{15}	0.03	0.01*	0.02	0.01	0.01	0.01*
Intensity, γ_{16}	-0.18	0.03***	-0.12	0.03***	-0.18	0.02***
Duration, γ_{17}	0.00	0.01	0.00	0.01	-0.01	0.01*
Comp. of format, γ_{18}	-0.01	0.04	0.00	0.04	-0.03	0.02
Comp. of provider, γ_{19}	0.05	0.02**	0.05	0.02*	0.04	0.01**
Dosage, γ_{110}	0.17	0.03***	0.11	0.04**	0.18	0.02***
Average acceleration						
Intercept, γ_{20}	-0.01	0.01	0.00	0.01	-	-
Mother married, γ_{21}	0.01	0.01	0.02	0.01*	-	-
Family income, γ_{22}	<0.01	<0.01	<0.01	<0.01	-	-
Down syndrome vs. other, γ_{23}	<0.01	0.01	-0.03	0.01*	-	-
Motor impairment vs. other, γ_{24}	<0.01	0.01	<0.01	0.01	-	-
Age at EI intake, γ_{25}	<0.01	<0.01	<0.01	<0.01	-	-
Intensity, γ_{26}	<0.01	<0.01	<0.01	<0.01	-	-
Duration, γ_{27}	<0.01	<0.01	<0.01	<0.01	-	-
Comp. of format, γ_{28}	<0.01	<0.01	<0.01	<0.01	-	-
Comp. of provider, γ_{29}	<0.01	<0.01	<0.01	<0.01	-	-
Dosage, γ_{210}	<0.01	<0.01	<0.01	<0.01	-	-
Random effect						
	Communication skills		Socialization skills		Daily living skills	
	Standard deviation	Variance component	Standard deviation	Variance component	Standard deviation	Variance component
Average initial status	0.25	0.06	0.34	0.11	0.08	0.01
Average instantaneous rate of growth ^a	0.23	0.05***	0.23	0.05	0.24	0.06***
Average acceleration	-	-	0.02	<0.01***	-	-
Level-1 effect	1.23	1.50	1.23	1.51	1.16	1.35

* $p < 0.05$.

** $p < 0.01$.

*** $p < 0.001$.

^a Average slope for daily living skills.

3.1. Communication skills

As hypothesized, a quadratic growth model showing slowly plateauing upward growth over time best represented the data for communication skills (Table 2). Predictors were entered at Level-2 to predict the intercept, average instantaneous rate of growth and average acceleration of communication skills (Table 3). The random effect associated with the instantaneous rate of growth at age 3 was statistically significant and was, therefore, retained in the conditional model.

With respect to EI service variables, greater service intensity was associated with lower levels of communication skills at EI exit and a slower rate of growth. Duration of services was also associated with lower levels of communication skills at EI exit. Comprehensiveness of provider was not predictive of communication skills at EI exit, but greater comprehensiveness predicted a faster rate

of growth. Finally, dosage was positively associated with higher communication skills at EI exit and a faster rate of growth.

Child and family characteristics were also predictive of communication skills. Greater family income predicted higher levels of communication skills at EI exit and faster rate of growth in these skills. Children with Down syndrome, compared to children with developmental delay of unknown etiology, showed significantly lower levels of communication skills at EI exit, although rate of growth did not differ across diagnostic group. Children who were older when they began EI services showed higher levels of communication skills at EI exit and faster growth in skills over time.

3.2. Socialization skills

Results from the unconditional model showed that quadratic growth was the best representation of the data for socialization skills (Table 2). However, the shape of growth was such that there

was acceleration in socialization skills during adolescence, in contrast to the plateau observed for communication skills. The random effects associated with both the instantaneous rate of growth at age 3 and the rate of acceleration were statistically significant and were, therefore, retained in our conditional model.

Results from the conditional model showed that greater service intensity was associated with lower levels of socialization skills at age 3 as well as a slower rate of growth (Table 3). In contrast, greater comprehensiveness of provider was associated with a higher average rate of growth. With regard to dosage, there was a positive relationship between hours of EI and socialization skills at EI exit, and rate of growth.

In addition to EI service variables, children of married mothers showed higher levels of socialization skills at age 3, a slower instantaneous rate of growth at age 3, and a greater rate of acceleration. In other words, children of married mothers have higher initial levels of socialization skills, but these skills do not increase at the rate observed for children of unmarried mothers. Into adolescence, however, children of married mothers show an advantage in socialization skills compared to their peers of unmarried mothers. Children with Down syndrome demonstrated fewer socialization skills but children who were older when they started EI services showed greater socialization skills at age 3. Similar to communication skills, greater family income predicted higher levels of socialization skills at EI exit and faster rate of growth in these skills.

3.3. Daily living skills

Results from an unconditional model showed that, unlike communication and socialization skills, the trajectory of daily living skills was best captured by linear growth (Table 2). The random effect associated with the instantaneous rate of growth at age 3 was statistically significant and, therefore, retained in the conditional model.

Results from the conditional model showed that greater service intensity was associated with lower initial levels of daily living skills at age 3 and smaller increases in daily living skills over time. In contrast, comprehensiveness of provider was associated with greater increases over time. With regard to EI dosage, increased hours of service was positively associated with daily living skills at age 3 as well as increases in daily living skills over time.

Greater family income predicted higher levels of daily living skills at EI exit and faster rate of growth in these skills, similar to the other domains of adaptive behavior. Children who were older when they entered EI showed higher initial levels of daily living skills and greater growth in this domain. Children with Down syndrome showed a slower rate of growth in daily living skills, although they did not differ from children with other diagnoses in daily living skills at age 3.

3.4. Additional analyses

Potential moderation effects of type of disability were also explored. Interactions of each variable indicating type of disability (i.e., Down syndrome vs. other, motor impairment vs. other) with each EI service variable (i.e., intensity, duration, comprehensiveness of format, comprehensiveness of provider, dosage) were created and entered individually as predictors at Level-2. None of these interaction terms reached statistical significance.

3.5. Prototypical cases

To illustrate the effect of dosage on each domain of adaptive behavior, predicted values for prototypical cases were plotted

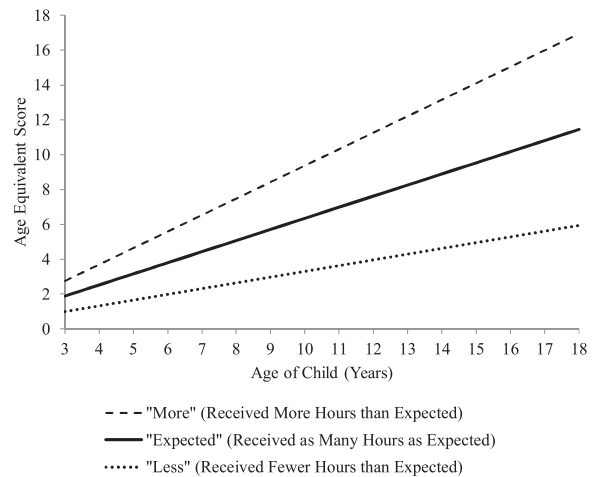


Fig. 1. Growth trajectories for communication skills by EI dosage level.

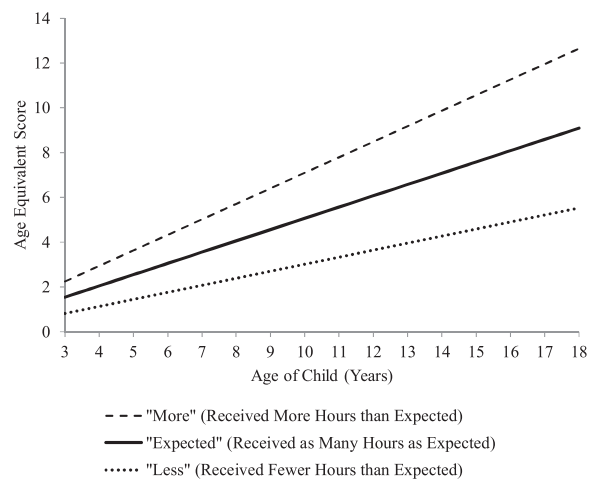


Fig. 2. Growth trajectories for socialization skills by EI dosage level.

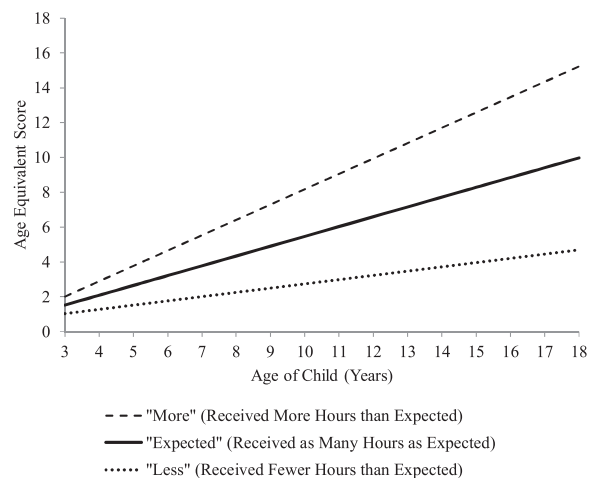


Fig. 3. Growth trajectories for daily living skills by EI dosage level.

(Figs. 1–3). These groups were created to represent children with values on the dosage variable one half SD below the mean (“less”), one half SD above the mean (“more”) and within one half SD of the mean (“expected”). One half SD corresponded to a difference of 1.78 h between the expected and received number of EI hours per month on average.

4. Discussion

The present analyses predicted growth in three domains of adaptive behavior from early childhood through adolescence based on the dosage of EI services. Importantly, these analyses controlled for traditional EI service measures (e.g., intensity, duration, comprehensiveness of provider, comprehensiveness of format) that vary based on individual child and family characteristics. Since experimental manipulation of dosage level is problematic, our approach comes as close as possible to isolating the effect of dosage from other factors. Our findings are correlational and should be interpreted with caution; however, they suggest that dosage level may have long-term impacts on adaptive behavior in children with developmental disabilities.

Children who received a greater dosage of EI services on average each month showed higher levels of adaptive behavior when they exited early intervention. These children continued to show greater growth across domains compared to their peers who received a lower dosage of EI services, controlling for a variety of other aspects of the EI service delivery and child and family background characteristics. It is important to note that, despite significant growth over time, children displayed skills substantially below their peers throughout the course of the study, as shown by the gap between age equivalency scores and chronological age, regardless of dosage.

Although most of these children would continue to have support needs in the long-term, those who received more hours of service than expected were likely to function more independently in educational, work and family settings. For example, a child who received only 1.78 more hours of service each month is predicted to function at the level of someone approximately 17 years of age by chronological age 18 with respect to communication skills (Fig. 1). With all other predictors held constant, a child who received 1.78 h fewer of service than expected each month is predicted to function at the level of someone approximately 6 years of age by chronological age 18, with all other factors being equal. In this example, the cumulative effect of a standard deviation difference in the number of hours of service (3.56 h) predicted a difference of 11 years with respect to functioning level in communication skills.

These findings suggest that Part C EI operation, practices, and policies may need to be geared toward increasing service hours. Since EI hours are of low intensity in general (e.g., 2–3 h per week), small increases in weekly hours may yield large benefits. The development and implementation of IFSPs is one area where EI programs could try to build in more service hours. Providers could be trained to emphasize the importance of extending EI hours and to work with families to understand their schedules and find room for additional service time and/or to understand when over the course of a year families have more time for EI (e.g., summer vacation).

This approach, however, runs counter to current trends. The mean number of hours of EI service is actually declining. Belcher, Hairston-Fuller, and McFadden (2011) reported that Part C EI hours planned and delivered was actually lower in 2011 than in both 2010 and 2009. States are being challenged to deliver EI services with budgets that have either been frozen or reduced (Belcher et al., 2011) and with minimal infrastructure support for database development that can monitor service delivery (Greenwood et al., 2011).

As an alternative to increasing the number of scheduled hours of service, practitioners could also reduce the number of missed hours of service. Studies have found that the amount of services authorized within an IFSP is often higher than the amount of services actually received (Block, Rosenberg, Kellar-Guenther, Robinson, & Goetze, 2014; Perry, Greer, Goldhammer, & Mackey-Andrews, 2001). The discrepancy between services authorized and used is larger for children with higher need (Block et al., 2014). Our findings may support this observation. Children from higher income families received greater than expected hours of service. Families with

more socioeconomic resources may be in a better position to advocate for their child's needs when negotiating the terms of the IFSP, or they may be more likely to follow through with scheduled service. Contextual factors such as culture, socioeconomic status, and geographic location may influence accessibility to services (Hallam et al., 2009). For example, families from low-income backgrounds may face additional barriers to service receipt that are outside of their control, such as transportation issues or greater uncertainty related to work demands. Given the importance of higher service dosages found in the present study, EI programs need better ways to monitor actual service delivery. For example, EI programs should flag cases where the difference between planned and used services is large and then investigate the reasons for the discrepancy (Hebbeler, Spiker, & Kahn, 2012). Currently, states are not required to monitor this discrepancy (Harbin, Rous, & McClean, 2005).

The present study did not capture the quality of the services provided, nor did it assess the extent to which parents implemented the strategies taught by EI providers. Improving the quality of EI service, rather than the quantity, may be another approach to improving child outcomes. For example, a recommended and required practice in EI service delivery is to provide intervention services within the child's natural learning environment. The natural learning environment is often operationalized as the child's home but can be any location that the child and family frequent. Best practices for transferring skills from the EI interventionist to a child's parent or caregiver include coaching strategies that demonstrate how families and other caregivers can integrate interventions into everyday routines and activities (Adams, Tapia & The Council on Children with Disabilities, 2013). These methods not only empower families and caregivers but can also spread and sustain the intervention activities over time and increase the extent to which they are individualized for each child and family (Campbell & Sawyer, 2007). Further, EI professionals have reported moderate confidence and frequent use of these teaching strategies and few barriers to this mode of intervention (Sawyer & Campbell, 2012). Future research should develop ways to document the true exposure to intervention strategies, including both formal and informal hours, and the relation of that exposure to developmental gains.

The importance of adding EI service hours runs counter to another trend. Between 1999 and 2011, the federal allocation per child for EI services decreased by more than 50%, adjusted for inflation (Lazara, Danaher, & Goode, 2011). A survey of Part C coordinators found that, on average, states draw on a variety of funding sources including 55% from the state, 31% from the federal government and 14% from local sources (Hebbeler, Greer, & Hutton, 2011). There was, however, wide variation in these percentages across states and only about one third of the states responding to the survey could identify the number of dollars available from each source. Further, the types of services that can and cannot be provided under these different sources vary (Hebbeler et al., 2012). For example, fee for service reimbursement models discourage the use of professional teams to provide EI services because only direct, face-to-face time with a child and family can be billed. Also, what is covered by Medicaid and private insurance varies by state and access to EI services is influenced by a family's access to insurance (Grant, 2005; Hallam et al., 2009). The complexity of the funding picture makes it difficult to understand how different funding policies are influencing service delivery or whether funds could be better utilized to extend service delivery.

Further, not only is there poor information on the total resources available for EI services, but also, other than studies focused exclusively on young children with autism (Penner et al., 2015), few studies linking cost and effectiveness have been conducted and those that do exist are dated (Barnett & Escobar, 1988; Warfield, 1994, 1995). Thus, states have little current information to guide them on how to allocate resources efficiently. State responses to

stretch limited resources over increasing numbers of children may dilute the services so severely that the desired outcomes are limited or negated (Hebbeler et al., 2012). The analyses presented in this study suggest that greater dosage levels are associated with higher adaptive behavior skills in the short term and in skill gains over the longer term. Thus, analyses that assess the impact and cost of different staffing and service delivery strategies allowable under different funding mechanisms are sorely needed.

Finally, in addition to the uniform results associated with dosage effects, there was consistency in the relation between greater comprehensiveness of provider and growth in communication, socialization and daily living skills. These findings suggest that interacting with a wider array of providers from different disciplines, rather than fewer providers, is beneficial for children's skill development. Using a team approach to care provision in the home has been found in other studies to yield important benefits. For example, home visits from a team of nurses and community health workers in comparison to a nurse alone have been associated with improved mental health outcomes (Roman, Raffo, & Meghea, 2012). The team-based model was found to utilize the different strengths of each home visitor and the added flexibility of having multiple providers available to provide visits increased the intensity of contact (Roman et al., 2007).

4.1. Limitations

This study has several limitations. The relatively small sample was recruited from EI programs in only two states and is not as ethnically or socio-economically diverse as the current population served by EI. Moreover, this sample included children 24 months or younger with one of three diagnostic categories only; therefore, the generalizability of the findings to children in EI more broadly may be limited. Only 18% of the variance in the number of hours of EI service received each month was explained by child and family characteristics measured at the start of the study. Future research should explore additional background characteristics that may explain variance in the number of hours of service received, as these characteristics may also explain long-term adaptive behavior outcomes.

This study did not account for potential changes in child cognitive and adaptive skills, for example, that may explain the number of service hours over the course of EI. For example, children with either large increases or declines in these skills may have had their service hours changed during the course of EI, affecting their overall dosage level. This study did not examine differences between the number of hours for which a child was eligible (i.e., on the IFSP) and the number of hours a child received. As an additional limitation, the trajectories of communication, socialization, and daily living skills were assessed separately although there are strong associations among them. Finally, this study did not examine the extent to which EI services trained parents to become interventionists themselves. In this study, we defined intensity as the number of hours of service provided by an EI provider. There is likely great variability between families in the extent to which intervention strategies modeled by EI providers are successfully adopted and incorporated into everyday family life (Innocenti & White, 1993).

4.2. Conclusions

The findings from this study indicate that higher dosage levels of Part C EI services are associated with higher levels of adaptive skills at exit from EI and continue to be associated with higher levels of performance over time, controlling for child and family characteristics as well as other measures of EI service. Future research should investigate the factors that mediate the impact of EI hours on long-term outcomes for this population. For example,

it is possible that exposure to a higher dosage and a greater comprehensiveness of service during the early childhood period leads parents to recognize the importance of these interventions and enable them to pursue additional services for their child throughout middle childhood and adolescence. Alternatively, schools may provide higher levels of service to children who enter their system having received more intense and more diverse services in EI. Additional research is needed to clarify the mechanisms underlying the long-term impacts of EI dosage on adolescence functioning. Nevertheless, the results from the present study support the need to invest early in significant services for children with disabilities. Early experiences are likely to set young children with disabilities on pathways leading to more independent adolescent functioning. Adolescents with disabilities who have greater communication, socialization, and daily living skills are more likely to enjoy a higher quality of life and have success in completing education, finding employment, and living independently (Hauser-Cram, Cannarella, Tillinger, & Woodman, 2013).

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